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THE ETHER DRIFT.

By AUGUSTUS TROWBRIDGE.

(Read April 22, 1910.)

At one time in the course of the development of physical science there were almost as many ethers postulated as there were phenomena to be explained. "Ethers were invented for the planets to swim in, to constitute electric atmospheres and magnetic effluvia, to convey sensations from one part of the body to another, till all space was filled several times over with ethers" (J. C. Maxwell).

Of all these ethers the only one which has survived to our day is that of Huygens which is, so to speak, working over-time in that it has to serve the electrician as well as the optician and it is rather disheartening to think that after more than one hundred years of unremitting labor all that we really know of its properties is this—it transmits any electro-magnetic disturbance with the speed of three hundred million meters per second.

When we admit the hypothesis of the ether with this property the question arises as to the nature of the mechanical bonds between ether and matter—there are of course three possibilities—when matter is in motion either the ether moves with it completely, or it is partially entrained or it is not entrained at all.

The simplest of these three possibilities is perhaps the first—that the ether is completely entrained by the moving matter—it is the simplest hypothesis because it would mean that matter, once associated with a given quantity of ether, remained so forever and if this were the case we might hope to explain matter in terms of the ether indissolubly associated with it. Unfortunately the celebrated experiment of Fizeau on the change of velocity of light with and against a stream of moving transparent matter rules out this simplest hypothesis of complete entrainment and leaves us the choice of an ether which is partially entrained by moving matter or one which is at rest absolutely and not entrained at all.

The reason why we are left with these *two* possibilities is that the increased velocity of propagation of light in the direction of the moving matter which Fizeau clearly demonstrated by direct experiment may be due to the ether being dragged by the moving matter or again it may be that the ether is at rest while the matter moving through it in some way affects the speed of propagation of light.

It has been found impossible to develop a theory based on the first of these possibilities as an hypothesis without introducing very arbitrary assumptions as to the relation existing between the ether and moving matter but if the second possibility be adopted as an hypothesis, viz: the ether at rest in space; it has been found possible, by the Dutch physicist, Lorentz, to develop a theory without further arbitrary assumptions which is in accord with results of a considerable number of optical experiments.

If the ether be at rest it will be in motion relative to the earth as it moves in its orbit and one might expect to find a different velocity of propagation of light according as it is measured with or against the supposed drift of the ether. The effect to be expected will depend on the ratio of the velocity of the moving earth to the velocity of light—this ratio in round numbers is one ten-thousandth. There are many ways of detecting a variation in the velocity of light by this amount and a number of physicists have attempted to detect such a change according as the velocity was measured along or across the direction of the supposed ether drift. All these experiments have given negative results and it is in favor of the theory of Lorentz that it explains the absence of this so-called first order effect when the light source and the observer are in motion together, but even on the Lorentz theory there should be an effect observable under these conditions which is proportional to the square of the ratio of the earth's velocity to the velocity of light—that is, proportional to one one-hundred millionth. This is called a second order effect.

Messrs. Michelson and Morley devised an experimental arrangement of sufficient sensitiveness to detect a second order effect due to relative motion of the earth and the ether, and they concluded that the earth must drag the ether along with it in its motion.

The results of this justly celebrated experiment of Michelson and Morley cannot be reconciled with the one theory which is in accord with the other optical phenomena such as stellar aberration and the Fizeau experiment, and which we have seen postulates an ether at rest in space and so it became necessary either to abandon the theory or to explain why the second order effect predicted by the theory should not have been detected in the Michelson-Morley experiment.

This explanation, due to Lorentz and Fitzgerald, was based on an assumed shortening of the linear dimensions of matter resulting from its motion through the ether. It is true that effects necessarily attendant on this hypothetical shortening have been sought in vain, but nevertheless this so-called Lorentz-Fitzgerald objection has tended to discredit the conclusions of Messrs. Michelson and Morley.

This, then, was the state of the question as to the relative motion of matter and ether when Professor C. E. Mendenhall and I undertook, in 1905, the work on which I am reporting at this time. (1) A well-developed theory based on the assumption of a stagnant ether which predicts a second order effect when the source of light and observer are in motion with respect to the ether. (2) Failure to detect any such effect by Michelson and Morley and the conclusion by them that the ether is at rest relatively to the moving earth and hence not stagnant. (3) The theory rehabilitated by an assumption that the linear dimension of matter is shortened by an amount of the second order when it moves through the ether. (To support this assumption good theoretical reasons were later adduced.)

In further experimentation it was obviously necessary to devise apparatus which should give indications which were independent of any hypothetical change of dimensions such as that suggested by Lorentz and Fitzgerald and be nevertheless sufficiently sensitive to detect the optical second order effect due to its motion relative to the ether.

The device adopted by us consisted of a source of light placed midway between two delicate electrical thermometers. Suppose the line joining the three points to lie in the direction of the motion

through space of the point of the earth's surface where the apparatus is set up, and suppose the relative positions of the three points be such that each thermometer receives the same amount of radiation from the source of light which lies between them. Now, if the ether be drifting across the apparatus in the direction joining the three points as the theory of Lorentz would have it drift, and if thereby the dimensions of the apparatus in this direction be shortened as Lorentz and Fitzgerald have supposed it to be shortened, *then* if the whole apparatus be rotated 180° about a vertical axis the distance between the three points cannot have altered so that if any change in the amount of radiation received by the two thermometers were to be noticed on rotating the apparatus through 180° it might be taken as proof positive that the ether was in motion relative to the apparatus. On the other hand, if the apparatus were sufficiently sensitive to detect a second order optical effect and no change took place on rotation, the objection could not be made that the effect was there but had been masked by shortening, since no hypothetical shortening could be conceived to alter the relative positions of three points on a straight line.

Thus the problem which confronted us was to devise apparatus capable of detecting a change in radiation received by its two parts so small as one one-hundred millionth part of this radiation—expressed differently it was to devise a pair of electrical thermometers capable of detecting a difference of temperature of less than the ten-millionth part of a degree and yet to so protect them that in spite of the fact that they must stand several feet apart that they should be subject to no irregular fluctuation in temperature of this order of magnitude. Also they must be mounted on a support so rigid that it may be rotated without introducing irregularities due to change of shape. After considerable trouble we have succeeded in satisfying both these conditions, but there remains a third more difficult condition which we have as yet not been able to wholly satisfy—this is that the two conditions just mentioned must remain satisfied when the thermometers are subjected to radiation from a light source standing between them which is at a

white heat and getting rid of energy at the rate of about one half a horse power.

In conclusion I would say that we confidently expect to be able to reduce the irregularities due to, as yet, uncontrolled temperature fluctuations—these now amount to about 8 times the effect we seek—two years ago they amounted to 1,000 times this effect.